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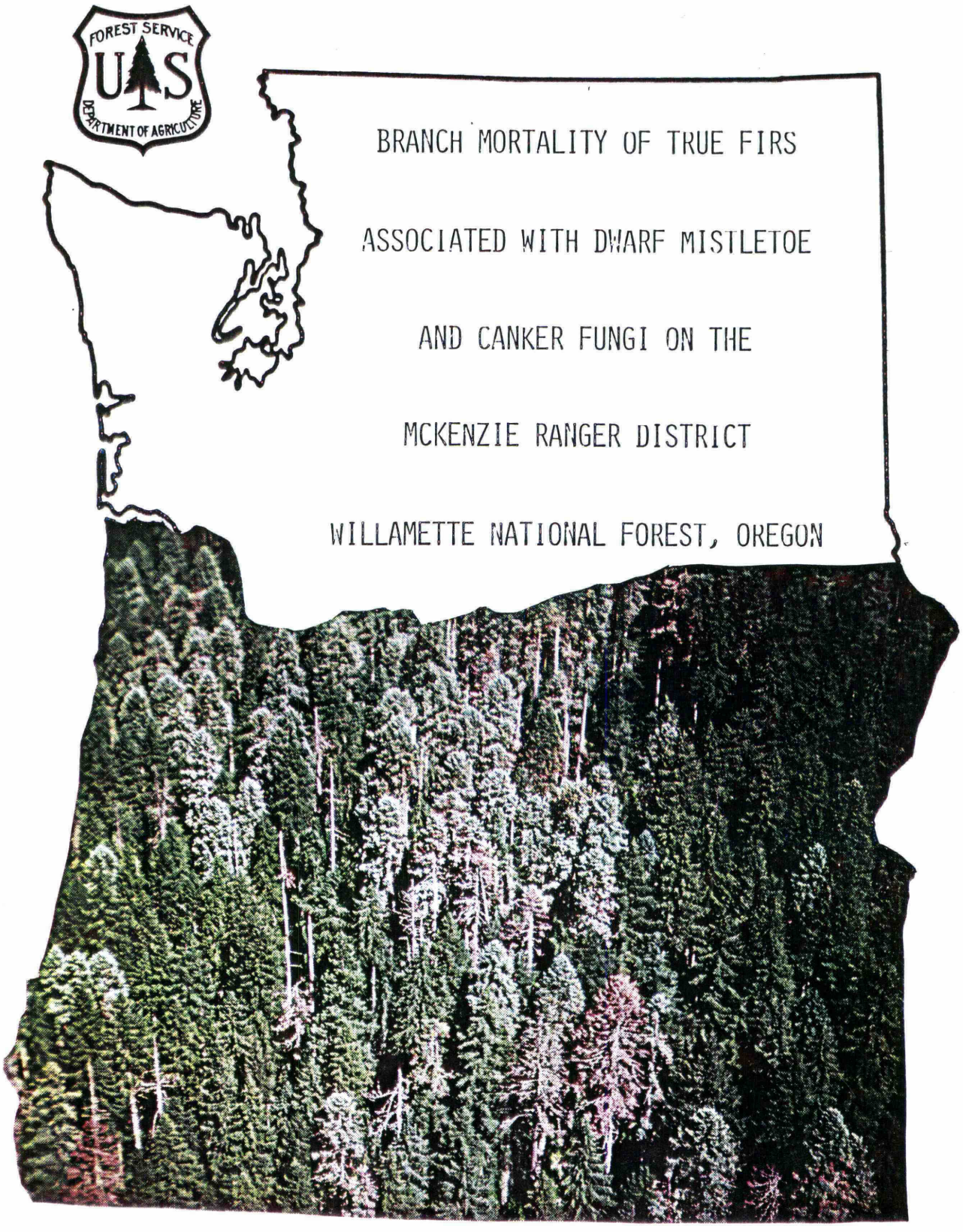
Forest Pest Management
Pacific Northwest Region



BRANCH MORTALITY OF TRUE FIRS

ASSOCIATED WITH DWARF MISTLETOE

AND CANKER FUNGI ON THE

MCKENZIE RANGER DISTRICT

WILLAMETTE NATIONAL FOREST, OREGON

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BRANCH MORTALITY OF TRUE FIRS ASSOCIATED WITH DWARF MISTLETOE AND CANKER FUNGI ON THE MCKENZIE RANGER DISTRICT, WILLAMETTE NATIONAL FOREST, OREGON

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Abstract

An evaluation was conducted on the McKenzie Ranger District, Willamette National Forest, Oregon, to determine cause of branch mortality in high elevation true fir stands. Nearly all of 53 trees examined with varying degrees of damage were infected with hemlock dwarf mistletoe. Damage was significantly greater in noble fir than in Pacific silver fir and was greatest in larger diameter trees. Three principal fungi were isolated from 55 percent of all branches examined: *Cytospora abietis, Cryptosporium pinicola,* and *Cylindrocarpon cylindroides*. Two of the three are known to be pathogenic. Presence of one or more of these fungi in branches was significantly correlated with presence of dwarf mistletoe or presence of open cankers, but not with branch condition (living, dying, or dead), branch age, age of mistletoe infections, or tree species. Branch mortality appeared to be caused by a combination of severe dwarf mistletoe infestation and infection by canker-associated fungi.

Introduction

Several canker-causing fungi are associated with dwarf mistletoe infections (Hawksworth 1972). Some of these fungi-mistletoe complexes kill limbs, tops, and even entire trees. Many of the fungi can infect and kill non-mistletoe-infected branches as well. Damage can reach epidemic proportions, especially when trees are weakened by environmental or other factors.

In 1976 and 1977, excessive branch mortality was observed in several stands of true fir (*Abies* sp.) on the Willamette National Forest in west-central Oregon. Preliminary observation showed that most damaged stands were infected with dwarf mistletoe. Since a possible association between dwarf mistletoe infections, canker fungi, and damage was suspected, a more thorough evaluation was conducted.

Objectives were to (1) examine a severely damaged stand on the McKenzie Ranger District, Willamette National Forest, Oregon; (2) determine cause of damage; (3) determine if correlations exist between damage intensity and tree size, age, and species; and (4) determine if correlations exist between cause and intensity of damage and various branch characteristics (age, species, etc.).

Methods

The evaluation was conducted on the McKenzie Ranger District (Figure 1). Stands experiencing damage were composed primarily of Pacific silver fir (*Abies amabilis*), noble fir (*A. procera*), and mountain hemlock (*Tsuga mertensiana*). Damage concentrations over a 100-square-mile area were delineated by sketch mapping from the air.

Aerial photographs were taken vertically at a scale of 1:8,000 and oblique photos were taken with a hand-held 35 mm camera. Aerial photographs were examined stereoscopically in an attempt to stratify stands into damage strata.

In September 1977, a heavily damaged area of about 150 acres was ground surveyed by examining equal numbers of trees of various size and damage classes. Only noble and Pacific silver fir were examined since branch mortality was insignificant in mountain hemlock.

The following data were recorded for each tree: (1) species, (2) dbh, (3) age, and (4) damage class. Damage class was determined by dividing the crown into thirds and rating each third on a scale of 0 to 2 based on amount of branch mortality. Damage class was the sum of the three ratings (0 to 6). This index was similar to that developed for rating dwarf mistletoe damage (Hawksworth and Lusher 1956).

Lower crown branches were examined on selected trees for condition (living, dying, or dead) and presence of dwarf mistletoe infections. Branch samples (6-inch sections) were collected to heights of 30 feet in the crown (Figure 2) and returned to the laboratory for culturing. An even number of dead, dying, and living branches was collected.

Branch age and age of dwarf mistletoe infections were recorded in the laboratory. Each branch section was then flamed in alcohol, outer bark covering swellings, cankers, or dwarf mistletoe infections was removed with a scalpel, and five wood chips (5 x 5 x 15 mm) were extracted with a wood gouge. Chips were plated on 2 percent water agar and incubated for 2 weeks. Fungal growth appearing from chips was hyphal-tipped and transferred to potato-dextrose agar (Scharpf 1969).

Canker-associated fungi, *Cylindrocarpon cylindroides* and *Cryptosporium pinicola*, were identified on the basis of spores produced on potato-dextrose agar in 4 weeks. Suspected isolates of *Cytospora abietis*, a canker-causing fungus, were transferred from potato-dextrose agar to alder twigs partially embedded in 2 percent water agar. *C. abietis* readily sporulated on this medium and was easily identified (Scharpf 1969). Fungi that were isolated infrequently were not identified.

All data were analyzed by stepwise regression and one-way analysis of variance.

Results

Extensive branch mortality (Figure 3) occurred on Pacific silver fir and noble fir growing at high elevations (4,000 to 5,000 feet) in the northwest quarter of the District. Damage near Bunchgrass Mountain (T. 14 S., R. 6 E., secs. 28 and 29) was especially severe. Nearly all of 53 trees examined in this area were infected with hemlock dwarf mistletoe (*Arceuthobium tsugense*) (Figure 4). True fir dwarf mistletoe (*A. abietinum*) was not detected.

Damage was significantly ($P = 0.01$) greater in noble fir than in Pacific silver fir, and it increased significantly with tree diameter (Figure 6). Tree age was nearly identical for all size classes (average = 82 years). Branch mortality was greater in lower crowns (Figure 5). Twenty-seven

percent of 626 lower crown branches examined were either dead or dying (Figure 7). Eighty-three percent of 626 lower crown branches were infected with dwarf mistletoe (Figure 8).

One-hundred-fifty-four branch segments were examined in the laboratory. Ninety percent of these were infected with dwarf mistletoe (Table 1). Infections averaged 8 years old. Fifty-nine percent of all these branches had open cankers, and there was no obvious correlation between branch condition and canker presence. Cause of cankers was not determined, although most cankers were associated with dwarf mistletoe infections.

Table 1.--Incidence of dwarf mistletoe, open cankers, and fungi in branches of Pacific silver fir (AA) and noble fir (AP).

Fungal Species Isolated	Number Branches Examined			Dwarf Mistletoe Present			Canker Present		
	Tot	AA	AP	Tot	AA	AP	Tot	AA	AP
				----------Percent----------					
Cytospora abietis	11	7	4	100	100	100	64	42	100
Cylindrocarpon cylindroides	45	31	14	100	100	100	60	53	79
Cryptosporium pinicola	50	41	9	96	95	100	71	79	33
Any	86	62	24	95	94	100	64	65	63
None or Others	68	48	20	84	88	75	53	56	45
Total	154	110	44	90	91	87	59	61	55

Cylindrocarpon cylindroides was isolated from 29 percent of all branches (Table 1). All branches with *C. cylindroides* also had dwarf mistletoe.

Sixty percent of *C. cylindroides*-infected branches had cankers. Fruiting bodies of the fungus were not observed on any infected branches in this evaluation. This is the first report of *C. cylindroides* infecting Pacific silver fir or noble fir in the United States. Pathogenicity was not tested.

Cryptosporium pinicola was isolated from 32 percent of all branches (Table 1). Ninety-six percent of all branches with *C. pinicola* also were infected with dwarf mistletoe. Seventy-one percent of *C. pinicola*-infected branches had cankers present. Fruiting bodies were not observed on infected branches. This is the first report of *C. pinicola* being isolated from dwarf mistletoe-infected branches.

Cytospora abietis was isolated from 7 percent of all branches (8 percent of mistletoe-infected branches) (Table 1). All branches with *C. abietis* also had dwarf mistletoe infections. More than half of the *C. abietis*-infected branches had cankers. Fruiting bodies were not observed on infected branches. *C. abietis* was almost equally common in living, dying, or dead branches as noted by Scharpf (1969). Although *C. abietis* has been

isolated from white fir (*Abies concolor*) and Shasta red fir (*A. magnifica* var. *shastensis*) in California (Wright 1942, Scharpf 1969) and from grand fir (*A. grandis*) in Idaho (Partridge 1966), it has never been reported infecting either Pacific silver fir or noble fir in the United States.

Presence of either *C. cylindroides, C. pinicola,* or *C. abietis* in a branch was significantly (P = 0.05) correlated with presence of dwarf mistletoe or presence of open cankers, but not with branch condition, branch age, age of mistletoe infections, or tree species. A total of 55 percent of all branches examined were infected with one or more of the three fungi (Figure 9). More than one fungus was occasionally isolated from a single branch.

Aerial photographs taken vertically at a scale of 1:8,000 were found to be totally unreliable for detecting branch mortality in this evaluation. Oblique photos taken with a hand-held 35 mm camera were more satisfactory because the oblique angle allowed viewing the sides of trees, and most mortality occurred in the lower crown.

Discussion

True fir stands in west-central Oregon exhibit extensive branch mortality and are heavily infected with dwarf mistletoe. The severity of branch mortality, however, appears to be greater than would normally be caused by dwarf mistletoe alone, especially since mistletoes are not a common true fir branch killer. Pathogenic canker-causing fungi have been known to infect dwarf mistletoe-infected branches. The fungus, *C. abietis*, is known to kill dwarf mistletoe-infected true fir branches in California (Scharpf 1969). Presence of this fungus was highly correlated with presence of dwarf mistletoe infection in California as it is in this evaluation.

Damage by *C. abietis* is accentuated by environmental factors that decrease tree vigor such as drought. In the year preceding our evaluation, Oregon experienced a severe drought. However, we feel the drought did not play a major role in branch mortality. Branch mortality was common before the drought, soil moisture seemed adequate in the affected areas, and branch mortality has been observed to the east and south of the evaluated area for several years.

In California, 20 percent of all branches bearing dwarf mistletoe were infected by *C. abietis*. The much lower incidence (8 percent) of dwarf mistletoe infections in this evaluation, prompted reexamination for other possible canker-related fungi. *Cryptosporium pinicola* and *Cylindrocarpon cylindroides* were isolated from 32 percent and 29 percent, respectively, of all branches examined. A total of 55 percent of all branches examined were infected with one or more of the three fungi.

Cylindrocarpon cylindroides is the imperfect state of *Nectria fuckeliana*. Ability of this fungus to infect and kill mistletoe- and nonmistletoe-infected branches has been demonstrated by others (Byler and Cobb 1972, Funk

et al. 1973). This fungus could, therefore, contribute to the branch mortality observed. The ability of *Cryptosporium pinicola* to infect and kill mistletoe- and nonmistletoe-infected branches has not been reported, but its prevalence in the area examined suggests that it may be contributing to branch mortality. Additional research is needed to confirm this. *C. pinicola* has been isolated from living white pine blister rust cankers in Idaho (Linder 1943).

Branch mortality was greatest in lower crowns and in larger trees. Dwarf mistletoe is generally more prevalent in lower crowns because most mistletoe seeds are deposited there. Large trees serve as larger targets than small trees. Some lower branch mortality may be due to normal suppression. Reasons for the greater amount of damage in noble fir than in Pacific silver fir are unknown, although there was slightly more dwarf mistletoe in branches of noble fir than in Pacific silver fir.

It is not clear to us why branch mortality has become so noticeable on the McKenzie District during the last 2 years. Similar damage has been prevalent in white fir stands on the Bend District, Deschutes National Forest, and on portions of the Umpqua and Winema National Forests since 1974, if not earlier. Damage has also been common in northern California. Trees on the McKenzie District have been infected by dwarf mistletoes for many years. Possibly inoculum levels of the canker fungi have greatly increased because of the close proximity to other areas with the same problem.

Branch mortality will continue on the McKenzie District and other areas where true firs have dwarf mistletoe. It is highly unlikely that the canker fungi will cause elimination of dwarf mistletoes from the stands, but the mistletoe infection level may be appreciably reduced.

Some trees on the District have already died because of extensive branch mortality and lack of sufficient foliage. Most trees that died were probably attacked by fir engravers (*Scolytus* sp.), but some may have been killed directly by the mistletoe-canker fungi complex. It is not possible to accurately predict when a tree with branch mortality will be killed. In northern California, red fir (*A. magnifica*) sawtimber with 70 percent live crown ratio before damage and with 50 to 70 percent of their crown missing, dying, or dead are considered high risks, and 20 to 30 percent will be killed by fir engravers within 1 year (George Ferrell, PNW Forest and Range Experiment Station, personal communication).

We estimate that noble and Pacific silver fir with 70 percent or less live crown ratio before damage would be high risks to Scolytus-kill when 50 percent or more of the crown is missing, dying, or dead (Damage Class 5 or 6). High risk trees should be salvaged before they die to capture their full potential value. True firs deteriorate rapidly after tree death.

Summary

1. In September 1977, an evaluation was conducted on the McKenzie Ranger District, Willamette National Forest, Oregon, to determine cause of branch mortality in high elevation true fir stands.

2. In a severely damaged stand, nearly all 53 trees examined with varying degrees of damage were infected with hemlock dwarf mistletoe.

3. Damage was significantly greater in large diameter than in small diameter trees.

4. Damage was significantly greater in noble than in Pacific silver fir. No other species was significantly damaged.

5. Three fungi were isolated from 55 percent of all branches examined: *Cylindrocarpon cylindroides, Cryptosporium pinicola,* and *Cytospora abietis*. Two of the three are known to be pathogenic.

6. Presence of one or more fungi in branches was significantly correlated with presence of dwarf mistletoe or presence of open cankers, but not with branch condition, branch age, age of mistletoe infections, or tree species.

7. Branch mortality appeared to be caused by a combination of severe dwarf mistletoe infestation and infection by canker-associated fungi.

Recommendations

Since canker-associated fungi and branch mortality are associated with dwarf mistletoe infections, recommendations for disease management are directed toward dwarf mistletoes.

1. True fir stands with extensive branch mortality should be surveyed by helicopter to accurately locate those most severely damaged. Standard aerial photography is not reliable for locating damage.

2. Severely damaged stands should be regenerated. Stands should be clearcut, with care taken to destroy all residuals left after logging.

3. Boundaries of clearcuts should be located in uninfected stands to prevent rapid spread of dwarf mistletoes from infected edge trees to plantation trees.

4. Douglas-fir may be planted safely in areas infested by hemlock dwarf mistletoe since this species of dwarf mistletoe cannot spread from hemlock or true firs to Douglas-fir. Noble fir, Pacific silver fir, subalpine fir, grand fir, mountain hemlock, western hemlock, and western white pine are the main hosts for hemlock dwarf mistletoe.

5. During stand improvement activities, discriminate against trees with dwarf mistletoe stem infections or upper crown infections. Vigorous trees will grow well despite of lower crown infections if they are provided adequate growing space.

6. Trees with 70 percent or less live crown ratio before damage and with 50 percent or more of their crowns missing, dying, or dead are considered high risk to attack and mortality caused by fir engravers (*Scolytus* sp.) and should, therefore, be salvaged.

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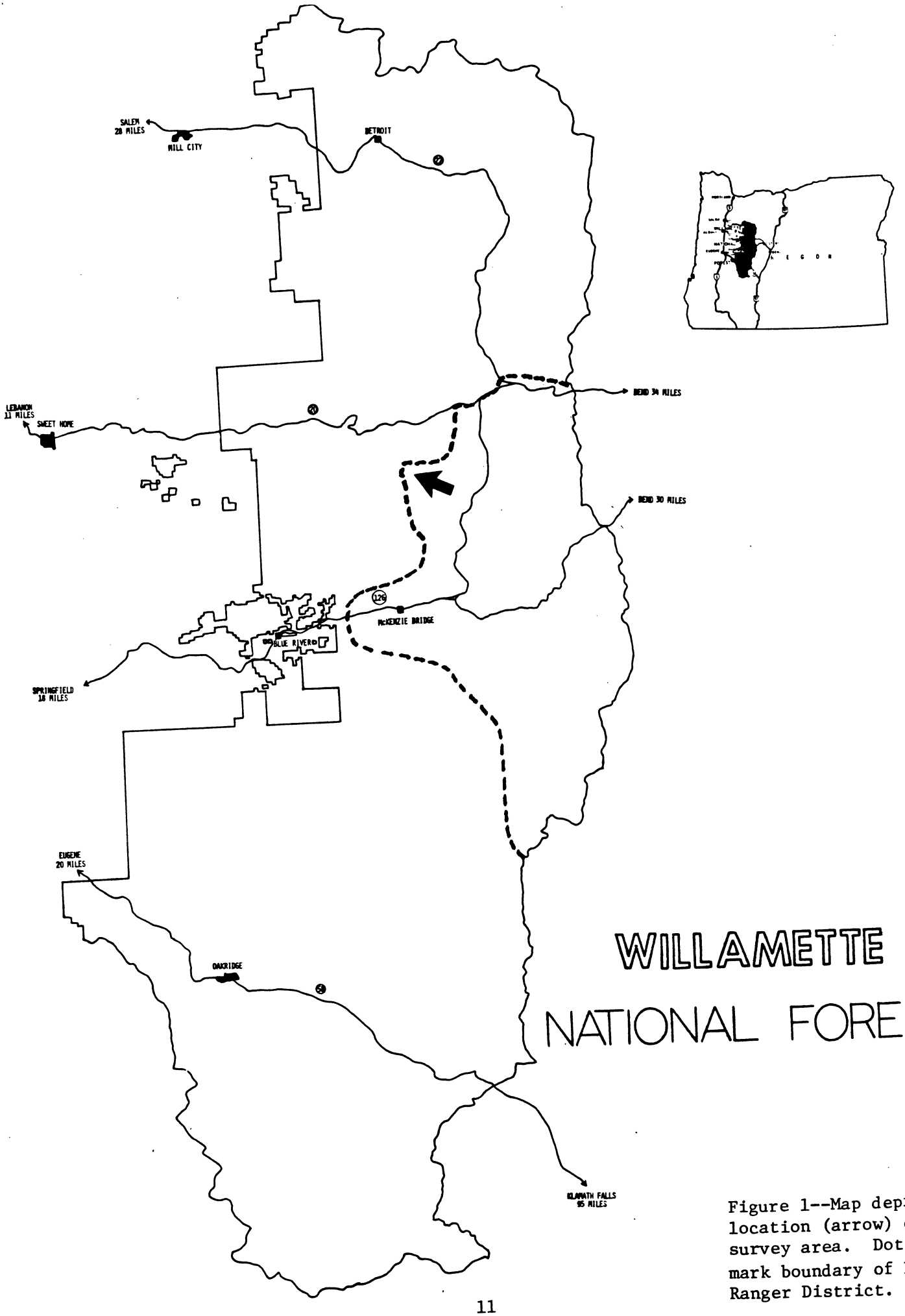


Figure 1--Map depicting location (arrow) of survey area. Dotted line mark boundary of McKenzie Ranger District.

Figure 2--Collecting lower crown branches of Pacific silver fir infected with dwarf mistletoe.

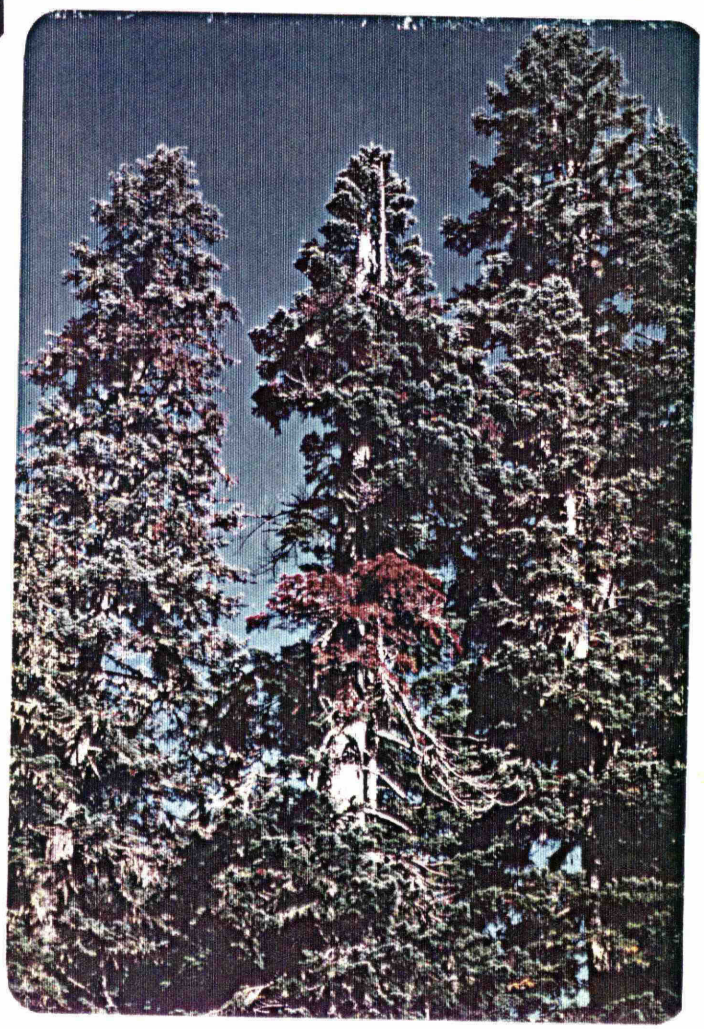


Figure 3--Branch mortality in old-growth Pacific silver fir.

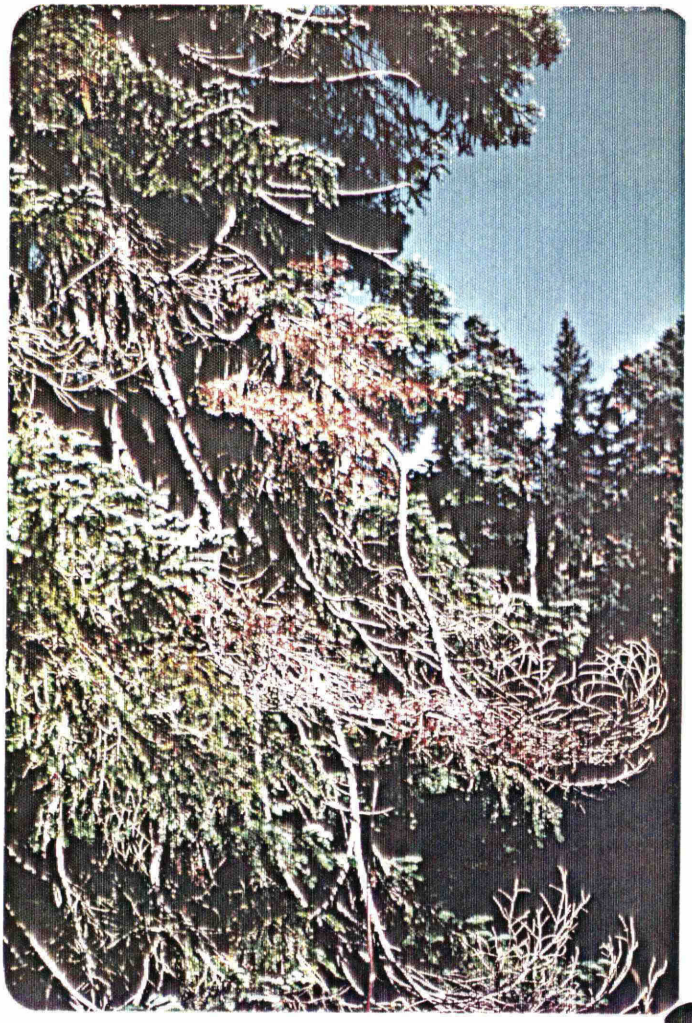


Figure 5--Branch mortality in lower crown of Pacific silver fir.

Figure 4--Branch swelling and mortality with old dwarf mistletoe infection.

Figure 6--Damage class of Pacific silver fir (*A. amabilis*) and noble fir (*A. procera*) by tree diameter (bh) class.

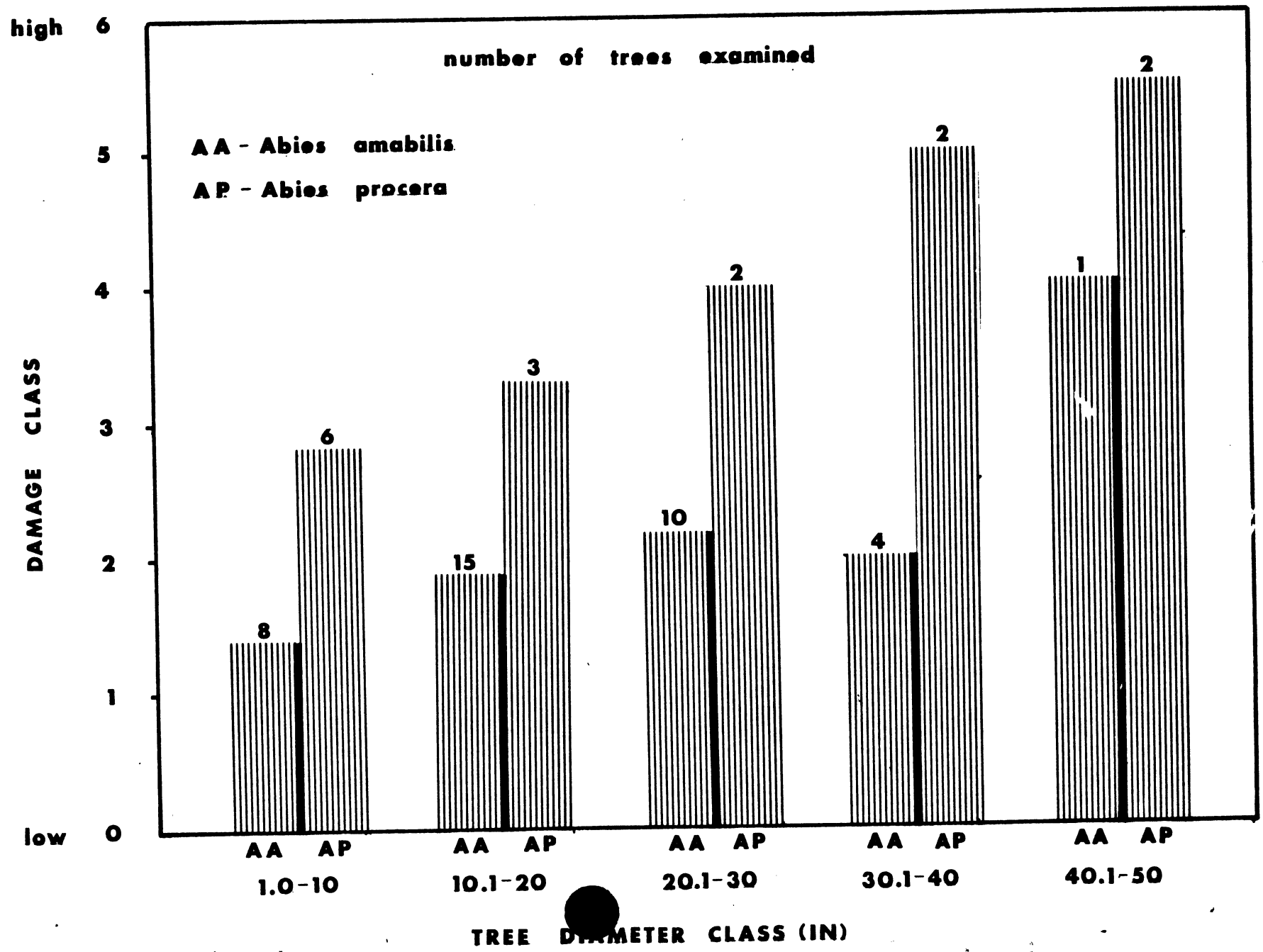
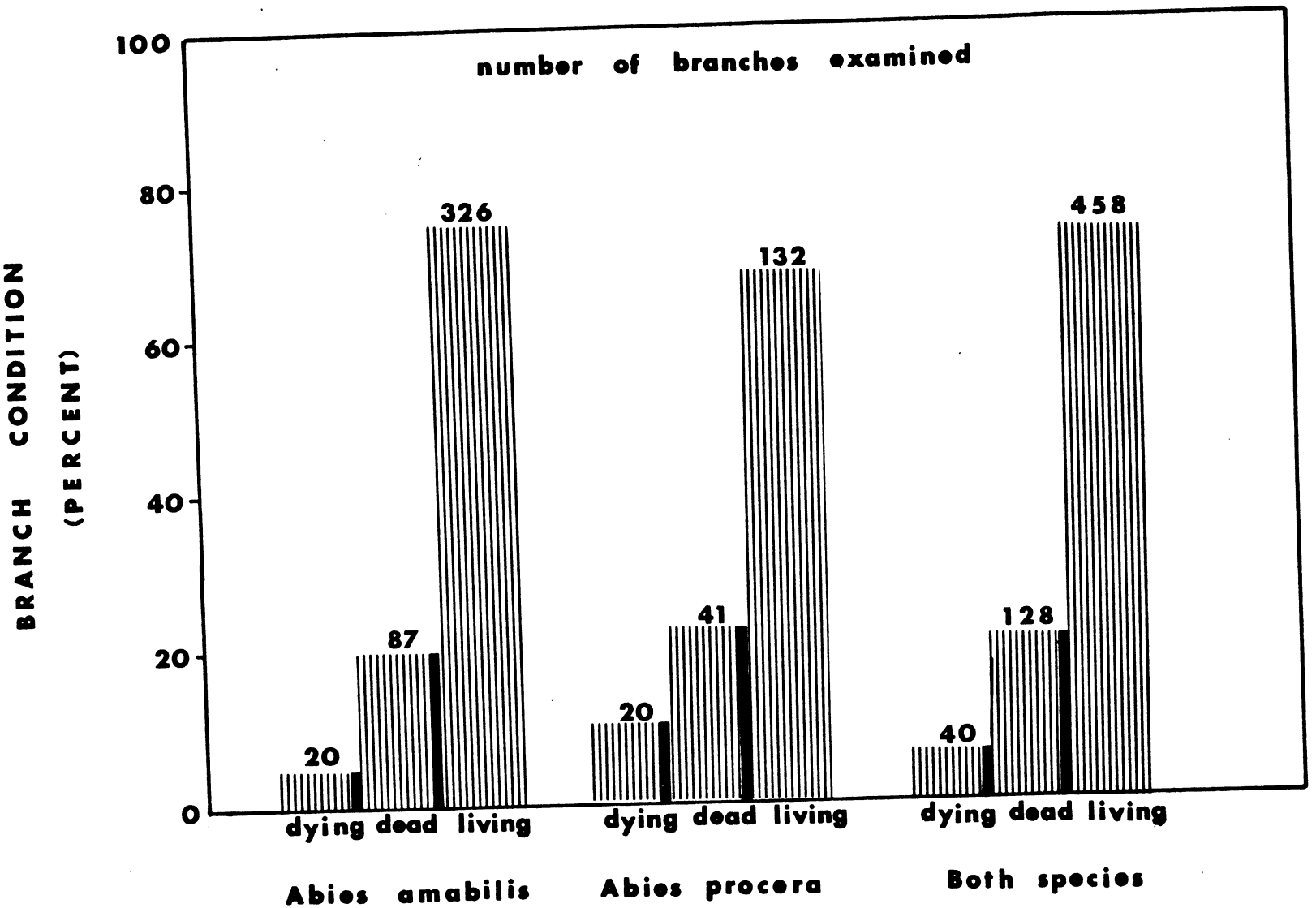


Figure 7--Percent of lower crown branches of Pacific silver fir (*A. amabilis*) and noble fir (*A. procera*) that were living, dying, or dead.



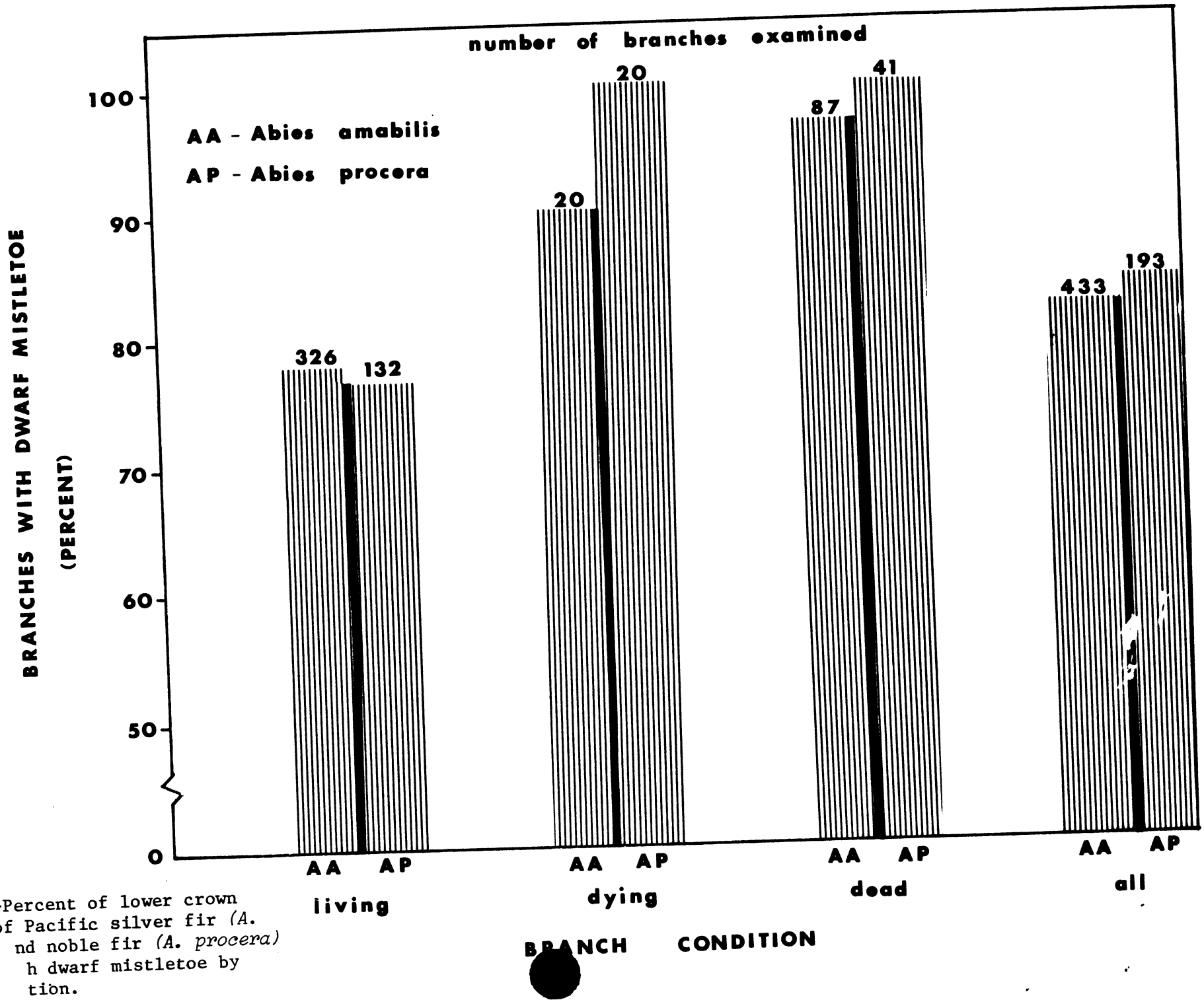


Figure 8--Percent of lower crown branches of Pacific silver fir (*A. amabili* nd noble fir (*A. procera*) infecte h dwarf mistletoe by branch tion.

Figure 9--Percent of lower crown branches of Pacific silver fir *(A. amabilis)* and noble fir *(A. procera)* infected with canker-associated fungi.